GLOBAL CLIMATE COALITION • GROWTH IN A GLOBAL ENVIRONMENT
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BACKGROUNDER

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Climate Models: Shortcomings and Limitations

General Circulation Models

General circulation models (GCMs) are computer representations of global climate. They are based on mathematical equations derived from our knowledge of the physics that govern the Earth-atmosphere system. By definition, "climate" encompasses a vast number of factors (cloud cover, air and ocean temperatures, rain and snowfall, air and ocean currents, barometric pressure, atmospheric composition, etc.). In GCMs, climate scientists typically divide the Earth's atmosphere into a three-dimensional grid, consisting of thousands of small boxes. Within each box, they attempt to represent mathematically the interactions among these and other factors (including geography and topography) that determine climate. The result is essentially a computer program that can create a picture of the climate based on variables entered by the modelers.

The picture is far from perfect, however. When testing the models, scientists attempt to reproduce existing climate conditions by feeding the computer climate data they know to be accurate. In an attempt to make the computer programs mirror current climate, scientists are forced to calibrate their models (i.e., adjust their equations) to better reflect actual climate. Calibrating the models does not mean eliminating their imperfections, but rather compensating for them.

Even after the models are calibrated, however, only the most general predictions (e.g., equator is warm, poles are cool, seasons change) are reasonably accurate. On a regional level (continents and subcontinents), the models cannot accurately predict climate. These limitations must be acknowledged when interpreting the climate simulations.

Greenhouse Scenario: Doubling Atmospheric Carbon Dioxide

The starting point for all predictions of catastrophic global warming is an assumption that levels of carbon dioxide (CO_2) in the atmosphere will double in the next century as a result of continuing CO_2 emissions from human activity (e.g., burning fossil fuel). While some scientists question the validity of this assumption, it is the basis for the predictions of increasing average global temperatures made by advanced GCMs. Even so, the various GCMs disagree significantly over the magnitude, ranging from 1.5 to 4.5 degrees Celsius (1992 IPCC report).

Limitations in the GCMs

GCMs are remarkably complex, often the products of teams of scientists and requiring the most powerful computers to operate. But, nevertheless, the models are not nearly as complex as the physics that determine climate, much of which is still not understood, by climate scientists. Ultimately, GCMs are only crude representations of the real world climate system.

In particular, the models do not adequately describe several key factors that will influence the climate's response to an assumed doubling of CO_2:

Role of the Oceans

First, the role of the oceans is not fully understood by scientists, and therefore cannot be reliably accounted for in models. Oceans cover about 70 percent of Earth's surface and currently hold about 300 times more CO_2 than the atmosphere. In addition, the ocean is responsible for transporting heat, which will greatly affect the magnitude and regional distribution of the response to a doubling of CO_2. Yet, modeling the dynamics of ocean and atmospheric interaction is more difficult and even less accurate than modeling either the ocean or the atmosphere. Improving confidence in the models will demand that ocean models be better developed and more fully integrated with atmospheric models.

Cloud Changes

Another major factor not well accounted for in GCMs is the response associated with clouds. As CO_2 doubles, changes are likely in cloud types, cloud coverage, and water content and reflectivity of clouds. These changes will certainly complicate the climate's response to a doubling of CO_2; increased cloud cover during the day has a significant cooling effect. Yet, the physics is not understood well enough for models to incorporate the effects of clouds with significant confidence. This is particularly important since natural water vapor is by far the most influential greenhouse gas, accounting for 70-90 percent of the heat absorbing capacity of the atmosphere.

Small-Scale Atmospheric Processes

Another source of inaccuracies in the models is the use of large blocks of land and atmosphere (as defined by the grid into which the models divide the atmosphere) whose characteristics are represented by only one set of data that does not accurately account for variations within that block. The size of the base measurement typically is about 90,000 square miles (about the size of Colorado), which precludes many small-scale, but important, climate related processes from being included in the models' calculations. This treatment contributes to the models' inability to predict climate in specific continental or sub-continental regions.

Improving the Models

General circulation models must be improved substantially before more confidence can be placed in the scenarios they generate. How much improvement is necessary? During the past 15 years, according to climate models, greenhouse gas emissions should have led to an increase in global temperatures of 0.3 to 0.5 degrees Celsius and an increase in U.S. temperatures of 0.5 to 1 degree Celsius. But NASA-analyzed satellite temperature readings for the same period show a slight cooling trend of a few hundredths of a degree Celsius.

Dr. Stephen Schneider, a climate modeler writing in **Global Warming: The Greenpeace Report (1990),** indicates that much improvement is still necessary. Schneider emphasizes the importance of developing and running models that accurately "couple," or integrate, the atmospheric and oceanic models and that can accurately represent regional climate changes:

> **"Our findings suggest that it is imperative to run high-resolution, coupled atmospheric, oceanic, cryospheric [ice cover], and land-surface sub-model models if regional, time-evolving scenarios of climatic changes are to have any hope of credibility. On the other hand, the more complex, three-dimensional models are not yet at an adequate phase of development to have trustworthy coupled atmosphere/ocean models that are both well verified and economical enough to be run over the hundred years needed for greenhouse-gas-transient simulations.... Since the agricultural and other environmental impacts of increasing greenhouse gases depend on the specific regional and seasonal distribution of climatic change, resolution of the transient-climate-response debate, among others, is critical for climatic-impact assessment and ultimate adaptive responses to the advent or prospect of increasing greenhouse gases."**

Schneider and other scientists suggest that reliable regional climate projections are at least 10 years in the future, and probably more. They agree that an expanded research effort is necessary to get the required computer power and to develop and routinely run the coupled climate models over the needed 50- to 100-year simulated time frames.

This research effort is already under way. The National Oceanic and Atmospheric Administration recently hosted a conference attended by climate modelers from around the world where they discussed the failure of current model predictions to match observed climate changes, as well as ways to improve the models.

Implications for Policymakers

How should policymakers treat the scenarios generated by climate models when developing a policy response? Policymakers must be aware of the limitations of computer models and their assumptions, recognizing that while they may provide scientists with some useful tools to explore the dynamics of future global climate, the scenarios cannot be considered an accurate picture of the future. The models are certainly not yet reliable enough to serve as a basis for billion-dollar public policy decisions that would affect energy prices, consumer costs and U.S. competitiveness in world markets.